

VLT/X-shooter spectroscopy of the candidate black-hole X-ray binary MAXI J1659–152 in outburst*

Ramanpreet Kaur^{1,2}, Lex Kaper¹, Lucas E. Ellerbroek¹, David M. Russell¹, Diego Altamirano¹, Rudy Wijnands¹, Yi-Jung Yang¹, Paolo D’Avanzo³, Antonio de Ugarte Postigo^{4,8}, Hector Flores⁵, Johan P.U. Fynbo³, Paolo Goldoni^{6,7}, Christina C. Thöne^{8,9}, Alexander van der Horst^{1,10}, Michiel van der Klis¹, Chryssa Kouveliotou¹¹, Klaas Wiersema¹² and Erik Kuulkers¹³

r.kaur@uva.nl

ABSTRACT

We present the optical to near-infrared spectrum of MAXI J1659–152, during the onset of its 2010 X-ray outburst. The spectrum was obtained with X-shooter on the ESO *Very Large Telescope* (VLT) early in the outburst simultaneous with high quality observations at both shorter and longer wavelengths. At the time of the observations, the source was in the low-hard state. The X-shooter spectrum includes many broad ($\sim 2000 \text{ km s}^{-1}$), double-peaked emission profiles of H, He I, He II, characteristic signatures of a low-mass X-ray binary during outburst. We detect no spectral signatures of the low-mass companion star. The strength of the diffuse interstellar bands results in a lower limit to the total interstellar extinction of $A_V \simeq 0.4 \text{ mag}$. Using the neutral hydrogen column density obtained from the X-ray spectrum we estimate $A_V \simeq 1 \text{ mag}$.

¹Astronomical Institute ‘Anton Pannekoek’, University of Amsterdam, Science Park 904, 1098 XH Amsterdam, the Netherlands

²Physics Department, University of Wisconsin-Milwaukee, Milwaukee, WI 53211, USA

³INAF, Osservatorio Astronomico di Brera, via E. Bianchi 46, 23807 Merate (LC), Italy

⁴Dark Cosmology Centre, Niels Bohr Institute, Juliane Maries Vej 30, Copenhagen, 2100, Denmark

⁵GEPI, Paris Observatory, CNRS, University of Paris-Diderot; 5 Place Jules Janssen, 92195 Meudon, France

⁶Laboratoire Astroparticule et Cosmologie, 10 rue A. Domon et L. Duquet, 75205 Paris Cedex 13, France

⁷Service d’Astrophysique, DSM/IRFU/SAp, CEA-Saclay, 91191 Gif-sur-Yvette, France

⁸IAA - CSIC, Glorieta de la Astronomía s/n, 18008 Granada, Spain

⁹Niels Bohr International Academy, Niels Bohr Institute, Blegdamsvej 17, 2100 Copenhagen, Denmark

¹⁰USRA, NSSTC, Huntsville, AL 35806, USA

¹¹Space Science Office, VP62, NASA/Marshall Space Flight Center, Huntsville, AL 35812, USA

¹²Department of Physics and Astronomy, University of Leicester, University Road, Leicester LE1 7RH, UK

¹³European Space Agency, European Space Astronomy Centre, P.O. Box 78, 28691, Villanueva de la Cañada, Madrid, Spain

The radial-velocity structure of the interstellar Na I D and Ca II H&K lines results in a lower limit to the distance of $\sim 4 \pm 1$ kpc, consistent with previous estimates. With this distance and A_V , the dereddened spectral energy distribution represents a flat disk spectrum. The two 10 minute X-shooter spectra show significant variability in the red wing of the emission-line profiles, indicating a global change in the density structure of the disk, though on a timescale much shorter than the typical viscous timescale of the disk.

Subject headings: (stars:) binaries: general, accretion, accretion disks - black hole physics - X-rays: binaries

1. Introduction

Transient low-mass X-ray binaries (LMXBs) form a sub-class of compact binary systems in which a neutron star or a black hole accretes matter from a low-mass companion through Roche-lobe overflow and occasionally undergo X-ray outbursts, during which their X-ray flux increases by several orders of magnitude in comparison to the quiescent state (Tanaka and Lewin 1995; van Paradijs and McClintock 1995). These outbursts have been observed on the timescales from a few weeks to several years. In outburst the X-ray emission of these systems is directly related to the accretion process and originates from the inner accretion disk while the optical emission is dominated from the reprocessed emission from the accretion disk with some contribution from the heated surface of the companion star. Many transient LMXBs have been studied in detail in the X-rays, but for only a few systems simultaneous high quality optical spectroscopy has been obtained during their outburst (e.g. GX 339–4: Soria et al. 1999, XTE J1118+480: Dubus et al. 2001). The latter is important to study the large-scale physical structure of the accretion disk.

On September 25, 2010, at UT 08h05, the *Burst Alert Telescope* (BAT; Barthelmy et al. 2005) onboard the *Swift* satellite was triggered by a transient source, first thought to be a gamma-ray burst: GRB 100925A (Mangano et al. 2010). On the same day, the *Monitor of All-sky X-ray Image* (MAXI) satellite (Matsuoka et al. 2009) also reported the discovery of a new transient, named MAXI J1659–152 (hereafter MAXI1659), at a position consistent with the GRB (Negoro et al. 2010). Subsequently, a number of space-based and ground-based observations were carried out to investigate the nature of this source (e.g. van der Horst et al. 2010, Vovk et al. 2010). Immediately after the BAT trigger, the *UltraViolet/Optical Telescope* (UVOT) onboard the *Swift* satellite (Roming et al. 2005) detected the optical counterpart of MAXI1659 with a magnitude of 16.8 in the white filter (Marshall 2010).

*Based on ESO-VLT/X-shooter observations obtained using the X-shooter guaranteed time GRB program (086.A-0073)

On September 25 at UT 23h39, the X-shooter spectrograph on the ESO *Very Large Telescope* (VLT) was pointed at the optical counterpart and registered an optical to near-infrared spectrum of MAXI1659 revealing the Galactic origin of the source (de Ugarte Postigo et al. 2010). The X-shooter spectrum showed various broad double peaked emission line profiles, as typically observed in X-ray binaries when they actively accrete.

Subsequent studies of the X-ray spectral and timing behaviour of the source (Kalamkar et al. 2011, Kennea et al. 2011, Muñoz-Darias et al. 2011) demonstrated that the system is a candidate black-hole X-ray binary. MAXI1659 also shows regular, though not really periodic dips in the X-ray intensity with a period of approximately 2.42h (Kennea et al. 2011, Kuulkers et al. 2011), pointing at a high orbital inclination. This is also interpreted as an orbital period and makes MAXI1659 the shortest orbital period black-hole X-ray binary candidate with an estimated distance of ~ 7 kpc and possibly an M5 dwarf companion (Kuulkers et al. 2010, Belloni et al. 2010, Kuulkers et al. 2011). Later on, the distance was suggested to be within 1.6 - 4.2 kpc (Miller-Jones et al. 2011). Like some other transient LMXBs (e.g. Swift J1753–0127, XTE J1118+480, GRO J0422+32, cf. Zurita et al. 2008) MAXI1659 is at a high Galactic latitude ($b = +16.49^\circ$).

In this paper, we report on the optical to near-infrared VLT/X-shooter spectra of MAXI1659 taken during the beginning of its 2010 X-ray outburst (see de Ugarte Postigo et al. 2010 for a preliminary report).

2. Observations and data reduction

We observed the optical counterpart of MAXI1659 on September 25, 2010, starting at UT 23h39 (MJD 55464.99) after triggering the X-shooter guaranteed time GRB program (086.A-0073, PI Fynbo) on the VLT. X-shooter is a wide-band, medium-resolution spectrograph, consisting of 3 arms. Each arm is an independent cross-dispersed echelle spectrograph with its own slit unit. The incoming light is split using dichroics, resulting in three spectral ranges: UVB (3000–5900 Å), VIS (5500–10200 Å) and NIR (10000–24800 Å). A detailed description of the instrument is provided by D’Odorico et al. (2006) and Vernet et al. (2011).

We obtained two spectra of MAXI1659 of 600s, starting at UT 23h39 and UT 23h50, at two different nodding positions on the slit. A slit width of $1.0''$ was used for the UVB arm while a $0.9''$ slit was used for the VIS and NIR arm; the corresponding resolving power is $R \sim 5100, 7500$, and 5700 , respectively. A telluric standard star (HIP083448) was observed immediately after the MAXI1659 observations. The spectrophotometric standard (Feige 110) was observed the night before, with the same slit configuration as used for MAXI1659. The seeing was $1.8''$ in the V band.

We used the ESO X-shooter pipeline version 1.2.0 (Goldoni et al. 2006, Modigliani et al. 2010) to obtain the wavelength calibrated and rectified two-dimensional spectra. The observations were reduced both in nodding and in staring mode, where in the latter case the two exposures were reduced separately. The one-dimensional spectrum was extracted and normalized using the

standard *IRAF* routines `apall` and `continuum`. The resultant spectrum was corrected for the Earth’s motion with respect to the local standard of rest (LSR) and the NIR spectrum was corrected for telluric absorption lines. The complete X-shooter spectrum was flux calibrated order-by-order relative to the flux table of spectrophotometric standard Feige 110. The obtained signal to noise ratio for the combined spectra is 46, 37 and 8 in the UVB, VIS and NIR arm, respectively.

We also analysed the archival optical and ultraviolet observations of MAXI1659 obtained with UVOT onboard the *Swift* satellite starting on September 26, 2010 at UT 0h07, 8 minutes after the X-shooter observations (see also Kennea et al. 2011). The image data of each of the six filters used were summed using `uvotimsum` and photometry of the source in individual sequences was derived with `uvotsource`. MAXI1659 is clearly detected at a significance of $> 50\sigma$ in all six filters (1900–5500 Å). Three trial extraction region radii of 3'', 4'', and 5'' were used, and the magnitude in each filter were derived from the range of output values.

3. Results

3.1. Emission lines

The X-shooter spectrum of MAXI1659 includes a number of emission lines of H, He I and He II. Fig. 1 displays the normalized X-shooter spectrum of MAXIJ1659 in the range 3000–10000 Å where all identified spectral lines are labelled at their respective wavelengths. Among the hydrogen lines, we detect the Balmer series from H α up to H η and the Paschen series from Pa β up to Pa–11. Fig. 2 displays the three strongest line profiles on a velocity scale showing a double-peaked structure. Table 1 lists all the spectral lines detected along with the line-profile parameters, measured using the *IRAF* routine `splot`.

All emission lines are very broad: the full width at half maximum (FWHM) is in the range of 1500–2000 km s $^{-1}$. The peak separation is measured as the difference in the central position of two gaussians fitted to the wing of each individual component; for the weaker emission-line profiles, it is difficult to determine whether they are also double-peaked. The peak separation varies from 918 to 1175 km s $^{-1}$, with a clear increasing trend among the H Balmer lines, except for H α (see Fig. 3). A similar trend in the peak-to-peak separation has been observed in GX 339–4 but among H, He I and He II lines (Wu et al. 2001). Such a trend indicates that higher excitation lines show a larger peak separation, i.e. they are formed closer to the black hole where the disk is hotter and more rapidly rotating. However, in our spectra, the He lines do not seem to follow this trend (Fig. 3). A possible explanation may be that the He lines are predominantly produced near the hot spot (see below). The disk velocity of the system is 156 ± 42 km s $^{-1}$, measured as the difference of the velocity of the center of the two peaks of a line with respect to its rest velocity. Only the strongest emission lines are used to measure the disk velocity.

In a number of LMXBs, a Bowen blend is detected at λ 4650–4660 Å, usually attributed to

the high excitation lines of the N III $\lambda 4634\text{--}4641$ Å/C III $\lambda 4647\text{--}4650$ Å formed due to the Bowen fluorescence mechanism (BFM, McClintock et al. 1975, Steeghs and Casares 2002; Casares et al. 2006). In MAXI1659 we detect a broad but weak emission line feature centered at 4628 Å with a FWHM of 2640 km s^{-1} which is likely due to the Bowen blend. However we detect no narrow peaks/structures corresponding to the individual N III components in this blend. The central velocity of this feature is -775 km s^{-1} , which is very different from the disk velocity of the system (156 km s^{-1}) and may be related to the disk wind. In another black hole binary XTE J1118+480, the Bowen blend was detected as a weak feature during outburst but was observed to vary in phase with He II 4686 Å (Dubus et al. 2001). Assuming that we observe the varying peak of the Bowen blend, we would expect to detect the red, rather than the blue component as the hydrogen and helium lines show the variability in the red component (see Section 3.2).

3.2. Emission-line variability

During the two 10 minute-observations of MAXI1659, the red wing of the emission-line profile shows significant variability (cf. Fig. 2). During the two observations, the FWHM and the peak separation remain constant while the equivalent width (EW) of the lines increases (e.g., the EW of H α increases from -7.3 ± 0.4 to -8.3 ± 0.4 Å, cf. Fig. 2). This variability is detected in different lines at the same velocity. As these lines originate in different parts of the spectrum (even in different spectrograph arms) this excludes the possibility that the observed variations are of instrumental nature.

Our X-shooter observations sample the orbital period of the source in which strong dipping is expected as estimated using an X-ray dip activity ephemeris (Kuulkers et al. 2012 in prep). The lack of simultaneous X-ray observations and, the fact that dips in this source show highly irregular structure which can last from a few minutes to as long as ~ 40 min (Kuulkers et al. 2011, Kuulkers et al. 2012 in prep), does not allow us to know which percentage of the X-shooter observations is affected by dips. However, the observed variability in MAXI1659 is similar to that observed in XTE J1118+480 (Dubus et al. 2001); in this system the He II 4686 Å line time series displays an S-wave pattern consistent with the photometric (i.e. orbital) period of 4.1h. According to Dubus et al. the variable component of the He II line (as well as that observed in H α , H β and the Bowen blend) most likely originates in the hot spot of the accretion disk where the accretion flow impacts on the disk.

3.3. Interstellar spectrum and distance to MAXI1659

The spectrum includes a number of interstellar lines: the Na I D and Ca II H&K lines, and a few diffuse interstellar bands (DIBs); their EW is listed in Table 2. Cox et al. (2005) measured the DIB spectrum in the strongly reddened sightline towards the X-ray binary 4U1907+97 ($E(B - V)$

= 3.45) and compared the EWs of several DIBs to those observed in the well-studied sightlines towards BD+631964 ($E(B - V) = 1.01$) and HD183143 ($E(B - V) = 1.28$). We calculated the EW ratio of the DIBs detected in MAXI1659 to those in the three mentioned sightlines, and arrive at a ratio of 0.06, 0.13 and 0.08, i.e. an $E(B - V)$ estimate of 0.21, 0.13 and 0.10 mag, respectively. As we do not know the value of R_V in the line of sight to MAXI1659, we used the R_V value for the respective sightlines (2.75, 3.1, and 3.3), and by using $A_V = E(B - V) * R_V$ we estimate A_V as 0.57, 0.40, and 0.33 mag, respectively. Thus, based on the DIB spectrum, A_V is 0.4 ± 0.1 mag.

Adding the *Swift*-UVOT data to extend the spectral coverage of the X-shooter spectrum towards the ultraviolet, we note a broad feature at 2175 Å (“the extinction bump”) which suggests a higher value of the optical extinction (see Section 3.4). Given the height of MAXI1659 above the Galactic plane ($z \sim 1$ kpc, see below), it may well be that the (still unidentified) DIB carriers are concentrated towards the Galactic plane, thus providing a lower limit to the total extinction.

The EW of the DIB at 5780 Å can be related to the neutral hydrogen column density N_H ; using Cox et al. (2005) a rough estimate of $N_H = 0.6 \times 10^{21} \text{ cm}^{-2}$ is obtained. Given the above, we also expect this to be a lower limit to the total N_H value. *Swift* X-ray observations (Kennea et al. 2011) indicate that the interstellar N_H value is $2.4 \times 10^{21} \text{ cm}^{-2}$.

An absorption feature is present in the red wing of the $H\beta$ emission line profile. This feature has been observed in other systems (e.g. Buxton and Vennes 2003, Soria et al. 2000, Dubus et al. 2001) and has been interpreted as a redshifted absorption component in $H\beta$; however, we think it most likely is due to the strong DIB at 4882 Å (Jenniskens and Desert 1994).

The Na I D and Ca II H&K interstellar lines are centered at a velocity of $14 \pm 10 \text{ km s}^{-1}$ with respect to the LSR of the solar environment. A kinematic model of the differential Galactic rotation (Brand and Blitz 1993) predicts a steady increase of the radial velocity in the direction of MAXI1659 from 0 km s^{-1} to 122 km s^{-1} at 8 kpc. The measured radial velocity distribution implies a lower limit to the distance of MAXI1659 of 4 ± 1 kpc. The corresponding height above the Galactic plane is $z \geq 1$ kpc.

3.4. Spectral energy distribution

Fig. 4 shows the flux-calibrated X-shooter spectrum of the optical counterpart of MAXI1659 extended to the ultra-violet region using the *Swift*-UVOT photometry. Due to estimated slitlosses, the X-shooter spectrum was scaled up by a factor of 1.75. The thus obtained SED is consistent with the UVOT photometry.

The neutral hydrogen column density increased during the outburst due to absorption intrinsic to the source (Kennea et al. 2011); the initial, and thus likely the interstellar value was $N_H = (2.4 \pm 0.3) \times 10^{21} \text{ cm}^{-2}$ on MJD 55464 at the start of the outburst. This corresponds (Güver and Özel 2009) to a visual extinction of $A_V = 1.1 \pm 0.2$ mag. This value is consistent with the value for

A_V necessary to remove the extinction bump at 2175 Å in the UVOT photometry.[†] The X-shooter spectrum and UVOT photometry are de-reddened adopting this value and using the extinction laws of Cardelli et al. (1989) and Mathis and Cardelli (1990). The dereddened spectral energy (SED) distribution becomes flat with a continuum rising to the blue as expected for LMXBs in outburst, as shown in red color in Fig. 4.

The whole UV–optical–NIR spectrum can be fitted by a single power law with slope $\beta = -1.37 \pm 0.14$ (where $\lambda F_\lambda = \lambda^\beta$). The spectrum cannot be fitted by a single temperature blackbody. For an optically thick, non-irradiated disk, we expect a power law with an index of $\beta \sim -1.33$ describing a multi-temperature blackbody extending from the optical/NIR regime to the far-UV (Frank et al. 2002). The intrinsic spectrum of MAXI1659 is remarkably consistent with this canonical spectrum. For most LMXBs in outburst, β ranges from -2.5 to -1.5 as observed from their optical/NIR spectra and originates in the irradiated outer disk (e.g. Hynes 2005). There is no significant variation in the spectral slope or colour of the UV–optical SED during the outburst (Kennea et al. 2011). This suggests that the non-irradiated disc dominates the emission throughout the entire outburst of MAXI1659.

4. Discussion

The optical to near-infrared spectrum of MAXI1659, taken during the beginning of the 2010 X-ray outburst, is consistent with a black-hole LMXB in the low-hard state (see Kennea et al. 2011 for the determination of the source state at the time of our X-shooter observations). The spectrum includes a number of double-peaked emission profiles revealing the fast rotation of the accretion disk. The observed trend in peak separation of the hydrogen Balmer line with excitation energy reveals the rotation profile of the accretion disk, where the inner and hotter regions of the disk rotate faster than the outer regions (Smak 1981).

Although we obtained only two spectra, a significant increase is observed in the red peak of the emission lines on a ten-minute timescale. This timescale is much shorter than the timescale associated with the outburst and the viscous timescale of the disk, estimated of the order of days to weeks for typical accretion disk parameters (Frank et al. 2002). It is possible that the observed change in the double-peaked emission lines is related to an S-wave pattern as observed in XTE J1118+480 (Dubus et al. 2001) caused by the revolving hot spot where the accretion stream from the low-mass companion star impacts onto the disk. This may then also explain why the He lines do not follow the same trend in varying peak separation as the H Balmer lines. An alternative explanation for the observed line-profile variability could be the warping of the disk propagating with time (Maloney and Begelman 1997). Another possibility could be the presence of a revolving

[†] We note that a slightly higher A_V (~ 1.6 mag) is found by fitting only the UVOT and optical X-shooter SED with a power-law reddened with the Cardelli et al. 1989 extinction law. This different approach will be presented in a forthcoming companion paper (D’Avanzo et al., in preparation).

structure in the accretion disk which has also been proposed as a possibly cause of the X-ray dipping behavior (Díaz Trigo et al. 2006, Díaz Trigo et al. 2009, Boirin et al. 2005).

The SED extending from the far-ultraviolet down to the near-infrared is flat when dereddened with $A_V = 1.1$ mag, consistent with an optically thick, non-irradiated accretion disk (Fig 4.). The visual extinction is consistent with that derived from the 2175 Å feature and the observed N_H from the X-ray observations. The DIBs indicate a smaller extinction, suggesting that the (unknown) DIB carrier(s) are concentrated towards the Galactic plane, apparently unlike the carrier of the 2175 Å feature. A supporting argument is that MAXI1659 is located far above the Galactic plane (~ 1 kpc for a distance of 4 kpc), like the other very few LMXBs (White and van Paradijs 1996). which are possibly ejected out of the Galactic plane due to large kick received during the supernova explosion; alternatively, they are remnants of the population of massive stars formed during early stages of the evolution of the Galaxy (Mirabel et al. 2001).

The measured spectral slope is similar to that observed in the black-hole LMXB XTE J1118+480: $\beta \sim -1.6$ (Dubus et al. 2001). In this source, synchrotron emission from the compact jet is known to contribute a large fraction of the optical/NIR flux in the low-hard state, making the spectrum redder than most usually reported for LMXBs (e.g., Hynes et al. 2003). It is plausible that the jet of MAXI1659 detected at radio frequencies (e.g. van der Horst et al. 2010) could contribute to the X-shooter spectrum of MAXI1659 as the source was in the low-hard state during the observation, which is commonly associated with compact jets seen in the optical/NIR (e.g. Buxton and Bailyn 2004; Russell et al. 2006; Coriat et al. 2009). It would be interesting to monitor the system during an outburst to study the disk revolution and longer -term evolution in response to the outburst. It will remain very difficult to detect the low-mass companion star and/or measure the mass of the black hole.

Acknowledgements

RK, RW and JPUF acknowledge support from the European Research Council starting grant.

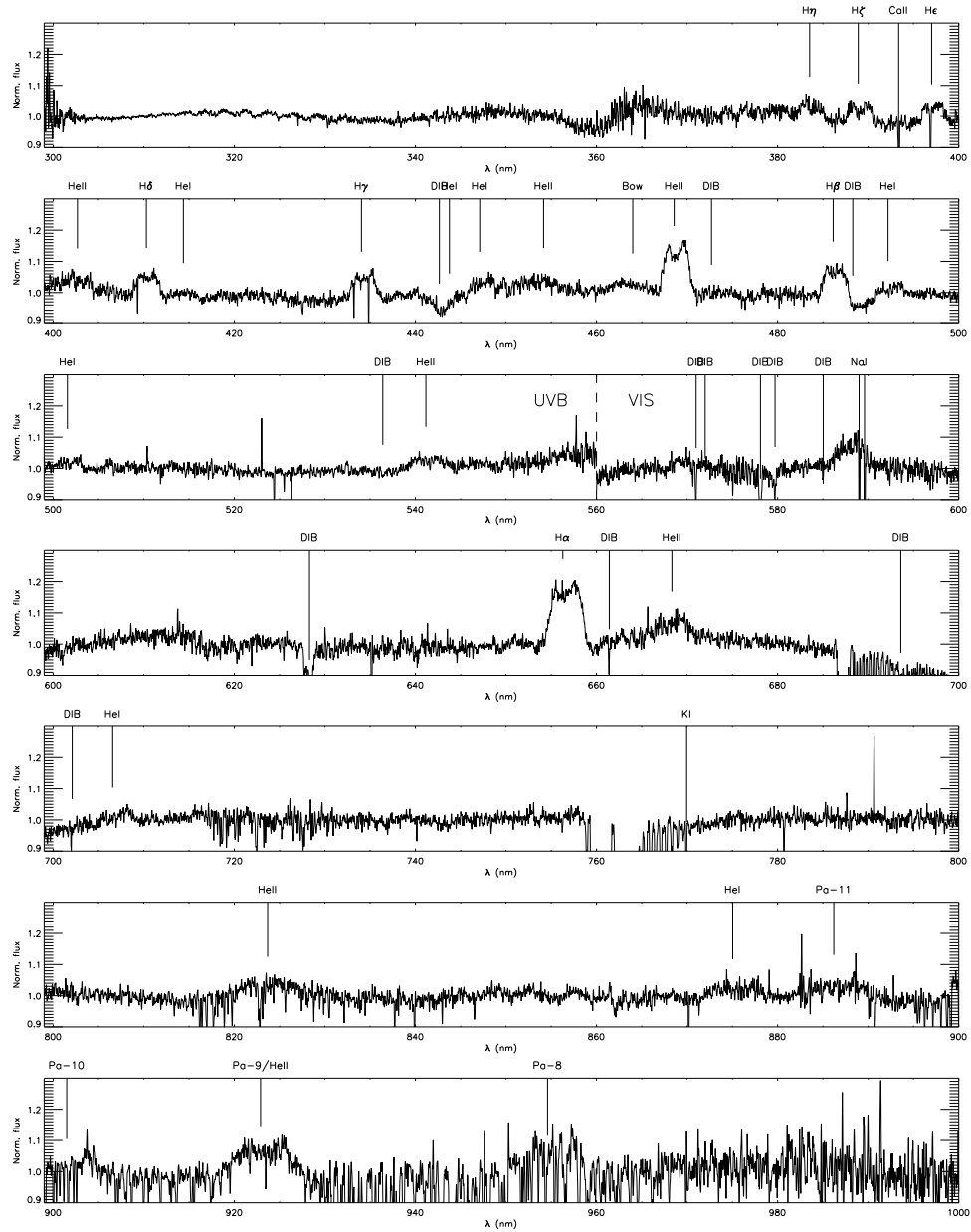


Fig. 1.— The X-shooter normalized spectrum of MAXI J1659-152 in the wavelength range 3000 - 10000 Å, with all identified spectral lines labelled at their respective wavelengths.

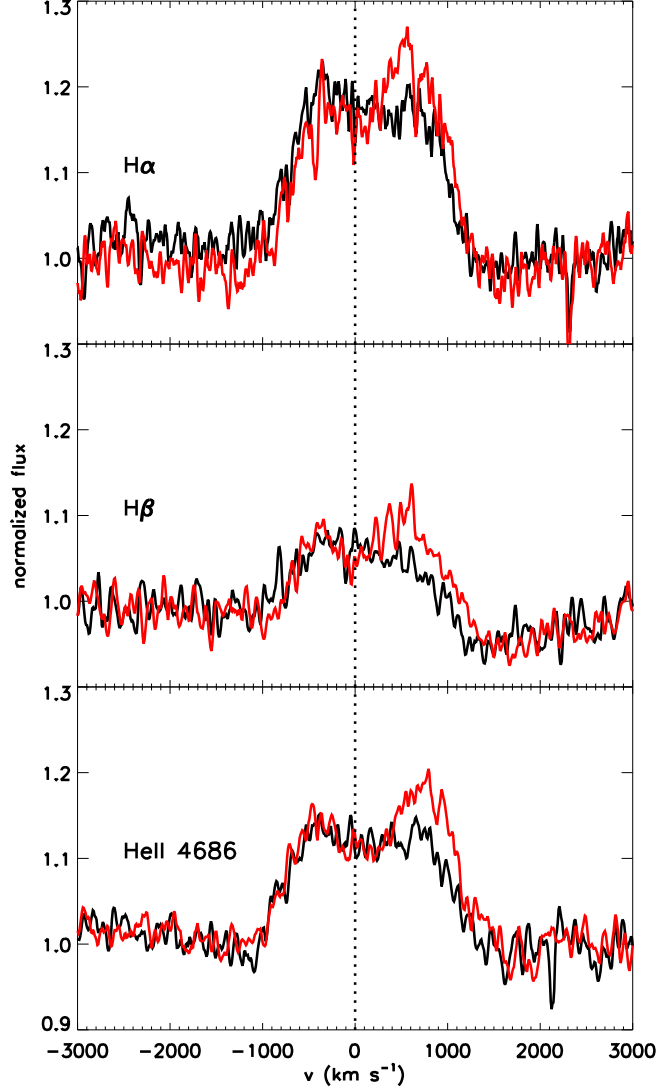


Fig. 2.— The observed double-peaked emission lines in the spectrum of MAXIJ1659 on a velocity scale (black : observation 1 - Sep 25 UT 23:39, red : observation 2 - Sep 25 UT 23:50). Note the variable red wing becoming significantly stronger on a timescale of 10 minutes. Zero on the velocity scale corresponds to the local standard of rest.

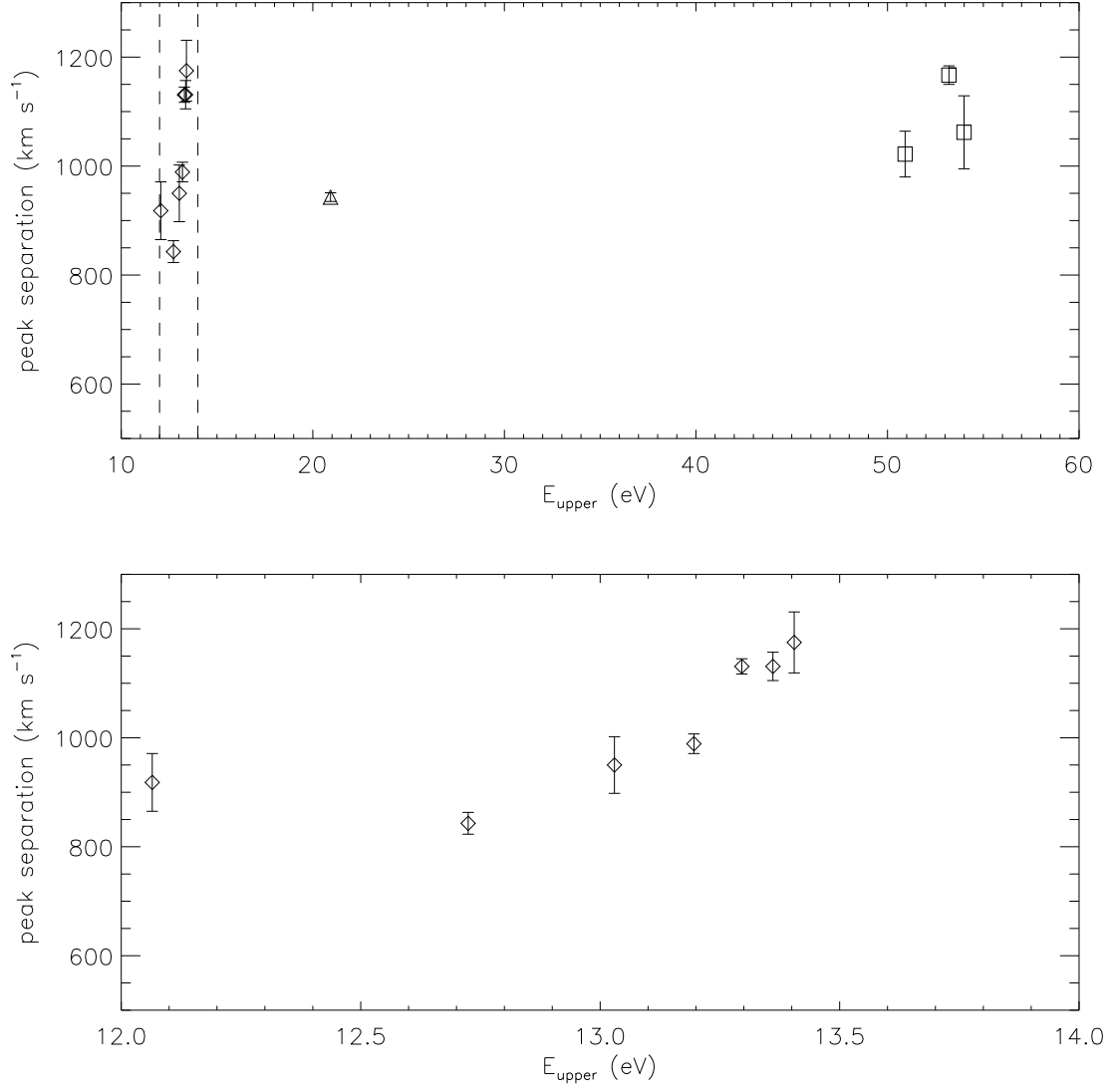


Fig. 3.— Peak separation versus the energy of the upper level for transitions of H I (diamonds), He I (triangles) and He II (squares). The region between dashed lines is enlarged in the lower panel.

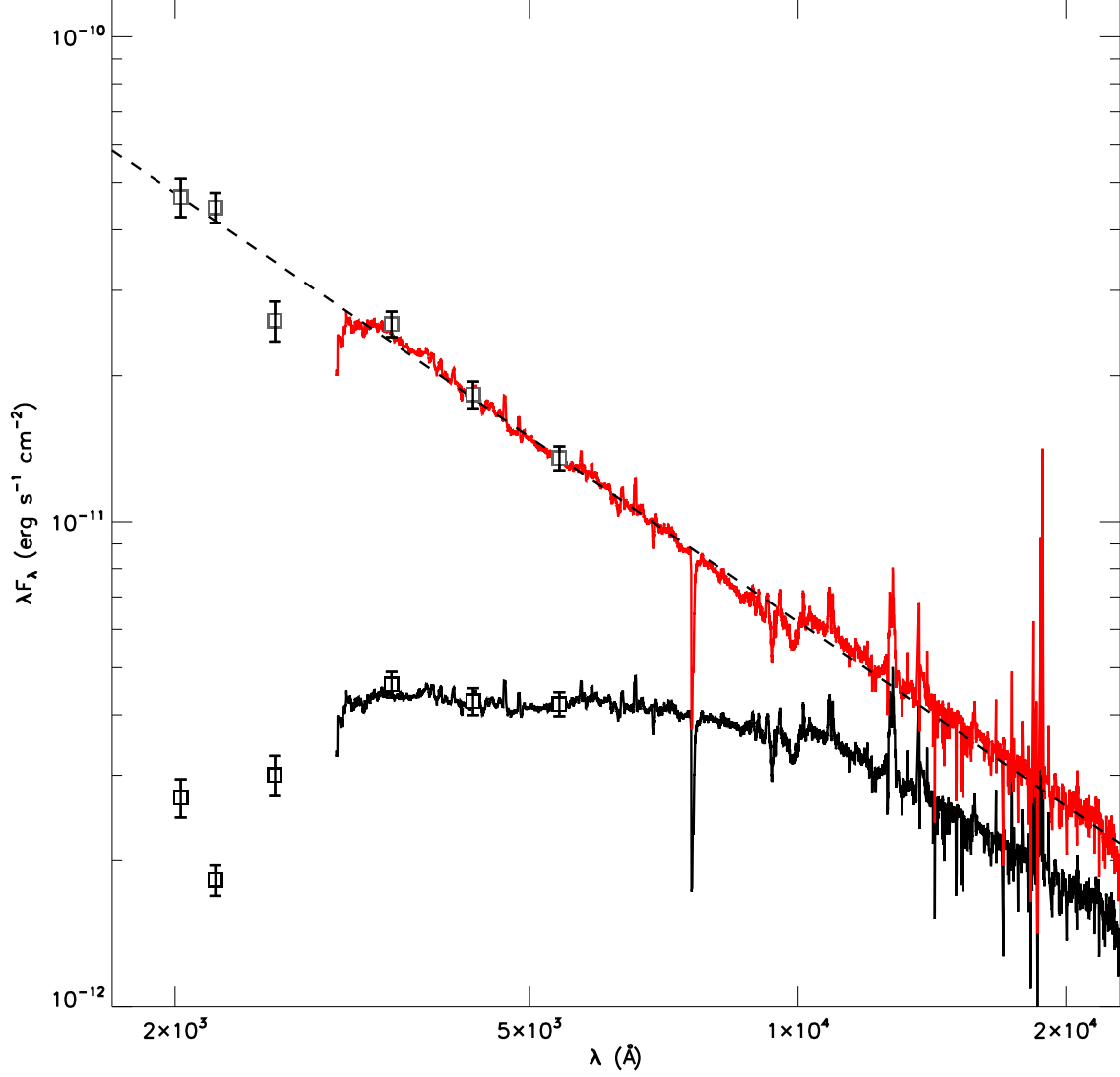


Fig. 4.— MAXI1659 flux-calibrated spectrum (black); dereddened spectrum, $A_v=1.1$ mag (red); *Swift*-UVOT photometry (squares). The spectrum was rebinned on 5 \AA and some features were clipped in order to show the general shape of the SED. The dotted line represents fit to the dereddened spectra with a power-law index of -1.37.

REFERENCES

- Barthelmy S.D., Barbier L.M., Cummings J.R. et al. *Space Sci. Rev.*, 120, 143 (2005).
- Belloni T.M., Muñoz-Darias T. and Kuulkers E. *The Astronomer’s Telegram*, 2926, 1 (2010).
- Boirin L., Méndez M., Díaz Trigo M., Parmar A.N. and Kaastra J.S. *A&A*, 436, 195 (2005).
- Brand J. and Blitz L. *A&A*, 275, 67 (1993).
- Buxton M. and Vennes S. *MNRAS*, 342, 105 (2003).
- Buxton M.M. and Bailyn C.D. *ApJ*, 615, 880 (2004).
- Cardelli J.A., Clayton G.C. and Mathis J.S. *ApJ*, 345, 245 (1989).
- Casares J., Cornelisse R., Steeghs D. et al. *MNRAS*, 373, 1235 (2006).
- Coriat M., Corbel S., Buxton M.M. et al. *MNRAS*, 400, 123 (2009).
- Cox N.L.J., Kaper L., Foing B.H. and Ehrenfreund P. *A&A*, 438, 187 (2005).
- de Ugarte Postigo A., Flores H., Wiersema K. et al. *GRB Coordinates Network*, 11307, 1 (2010).
- Díaz Trigo M., Parmar A.N., Boirin L., Méndez M. and Kaastra J.S. *A&A*, 445, 179 (2006).
- Díaz Trigo M., Parmar A.N., Boirin L. et al. *A&A*, 493, 145 (2009).
- D’Odorico S., Dekker H., Mazzoleni R. et al. *Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series*, volume 6269 of *Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series* (2006).
- Dubus G., Kim R.S.J., Menou K., Szkody P. and Bowen D.V. *ApJ*, 553, 307 (2001).
- Frank J., King A. and Raine D.J. *Accretion Power in Astrophysics: Third Edition* (2002).
- Goldoni P., Royer F., François P. et al. *Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series*, volume 6269 of *Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series* (2006).
- Güver T. and Özel F. *MNRAS*, 400, 2050 (2009).
- Hynes R.I. *ApJ*, 623, 1026 (2005).
- Hynes R.I., Haswell C.A., Cui W. et al. *MNRAS*, 345, 292 (2003).
- Jenniskens P. and Desert F.X. *A&AS*, 106, 39 (1994).
- Kalamkar M., Homan J., Altamirano D. et al. *ApJ*, 731, L2 (2011).

Table 1: Parameters of spectral lines detected in the X-shooter spectrum of MAXI1659. The first column lists the identification and rest wavelength of the spectral line, second column the equivalent width, third column the full width at half maximum and the fourth column the peak separation. A line is marked with ‘B’ in case of a blend.

Line (λ_o) (Å)	EW (Å)	FWHM (km s ⁻¹)	peak-separation (km s ⁻¹)
H η 3835.38	-0.98 ± 0.09	1895 ± 87	1175 ± 56
H ζ 3889.05	-1.18 ± 0.03	2035 ± 69	1131 ± 26
H ϵ 3970.07	-0.70 ± 0.09	1618 ± 129	1131 ± 14
H δ 4101.73	-1.57 ± 0.07	1730 ± 195	989 ± 18
H γ 4340.46	-1.68 ± 0.08	1881 ± 62	950 ± 52
H β 4861.33	-1.55 ± 0.07	1404 ± 58	843 ± 20
H α 6562.80	-6.30 ± 0.10	1567 ± 28	918 ± 53
P ϵ 9545.972	–	–	–
Pa δ 10049.37	–	–	–
Pa γ 10938.10	-12.40 ± 0.5	1660 ± 89	–
Pa β 12818.08	–	–	–
Br γ 21655.29	–	–	–
He II 4025.60	-0.666 ± 0.12	1939 ± 155	1062 ± 67
He II 4541.59	B	–	–
He II 4685.71	-3.88 ± 0.22	1785 ± 26	1022 ± 42
He II 5411.53	–		1167 ± 17
He II 6683.20	-1.88 ± 0.14	1537 ± 147	–
He II 8236.79	–	–	–
He II 8801.419	B	–	–
He II 9225.32	B	–	–
He I 4143.76	-0.18 ± 0.04	–	–
He I 4471.47	B	–	–
He I 4921.93	-0.57 ± 0.05	–	–
He I 7065.71	-0.61 ± 0.14	–	–
He I 8750.47	B	–	–
He I 9210.05	B	–	–
He I 10829.09	-17.69 ± 1.30	1623 ± 22	943 ± 8
C III/N III 4640	-1.05 ± 0.10	2639 ± 158	–

- Kennea J.A., Romano P., Mangano V. et al. *ApJ*, 736, 22 (2011).
- Kuulkers E., Ibarra A., Pollock A. et al. *The Astronomer’s Telegram*, 2912, 1 (2010).
- Kuulkers E., Kouveliotou C., van der Horst A.J. et al. in press, (astro-ph/1102.2102) (2011).
- Maloney P.R. and Begelman M.C. *ApJ*, 491, L43 (1997).
- Mangano V., Hoversten E.A., Markwardt C.B. et al. *GRB Coordinates Network*, 11296, 1 (2010).
- Marshall F.E. *GRB Coordinates Network*, 11298, 1 (2010).
- Mathis J.S. and Cardelli J.A. *Bulletin of the American Astronomical Society*, volume 22 of *Bulletin of the American Astronomical Society*, 861 (1990).
- Matsuoka M., Kawasaki K., Ueno S. et al. *PASJ*, 61, 999 (2009).
- McClintock J.E., Canizares C.R. and Tarter C.B. *ApJ*, 198, 641 (1975).
- Miller-Jones J.C.A., Madej O.K., Jonker P.G. et al. *The Astronomer’s Telegram*, 3358, 1 (2011).
- Mirabel I.F., Dhawan V., Mignani R.P., Rodrigues I. and Guglielmetti F. *Nature*, 413, 139 (2001).
- Modigliani A., Goldoni P., Royer F. et al. *Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series*, volume 7737 of *Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series* (2010).
- Muñoz-Darias T., Motta S., Stiele H. and Belloni T.M. *MNRAS*, 415, 292 (2011).
- Negoro H., Yamaoka K., Nakahira S. et al. *The Astronomer’s Telegram*, 2873, 1 (2010).
- Roming P.W.A., Kennedy T.E., Mason K.O. et al. *Space Sci. Rev.*, 120, 95 (2005).
- Russell D.M., Fender R.P., Hynes R.I. et al. *MNRAS*, 371, 1334 (2006).
- Smak J. *Acta Astron.*, 31, 395 (1981).
- Soria R., Wu K. and Hunstead R.W. *ApJ*, 539, 445 (2000).
- Soria R., Wu K. and Johnston H.M. *MNRAS*, 310, 71 (1999).
- Steeeghs D. and Casares J. *ApJ*, 568, 273 (2002).
- Tanaka Y. and Lewin W.H.G. W. H. G. Lewin, J. van Paradijs, & E. P. J. van den Heuvel, (ed.) *X-ray Binaries*, 126–174 (1995).
- van der Horst A.J., Granot J., Paragi Z. et al. *The Astronomer’s Telegram*, 2874, 1 (2010).
- van Paradijs J. and McClintock J.E. W. H. G. Lewin, J. van Paradijs, & E. P. J. van den Heuvel, (ed.) *X-ray Binaries*, 58–125 (1995).

- Vernet J., Dekker H., D’Odorico S. et al. in press (astro-ph/1110.1944) (2011).
- Vovk I., Kuulkers E., Alfonso-Garzón J. et al. The Astronomer’s Telegram, 2875, 1 (2010).
- White N.E. and van Paradijs J. ApJ, 473, L25 (1996).
- Wu K., Soria R., Hunstead R.W. and Johnston H.M. MNRAS, 320, 177 (2001).
- Zurita C., Durant M., Torres M.A.P. et al. ApJ, 681, 1458 (2008).

Table 2: Detected interstellar lines and diffuse interstellar bands with their measured equivalent width.

Line (Å)	EW (Å)
Ca II λ 3933.66	0.41 ± 0.02
Ca II λ 3968.47	0.30 ± 0.02
Na I λ 5889.95	0.60 ± 0.06
Na I λ 5895.92	0.58 ± 0.01
K I λ 7699.0	0.23 ± 0.01
DIB λ 4427	2.69 ± 0.28
DIB λ 5710	0.19 ± 0.02
DIB λ 5781	0.51 ± 0.06
DIB λ 5797	0.60 ± 0.06
DIB λ 6283	1.41 ± 0.02
DIB λ 6614	0.15 ± 0.02